Baryon bound states of three hadrons
with charm and hidden charm

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In this talk, we show our recent theoretical results for three-body systems in the charm sector which are made of three hadrons and contain one nucleon, one D meson and in addition another meson, $\overline{D}$, K or $\overline{K}$.

1 Introduction

While the three baryon system has been a subject of intense theoretical study, it has only been recently that attention was brought to systems with two mesons and one baryon. The low lying excited $J^P = 1/2^+$ Λ and Σ states were described in [1], and N^* states in [2], combining Faddeev equations and chiral dynamics. A N^* state around 1920 MeV was predicted in [3] as a molecule of $NK\overline{K}$, corroborated in [4] and [5] by Faddeev equations. For three mesons systems, the X(2175) (now $\phi(2170)$) was explained as a resonant $K\overline{K}\phi$ system in [6]. Similarly the $K(1460)$ is explained as a $KK\overline{K}$ state in [7].

In a recent work we study the three body systems in the charm sector, and use the Fixed Center Approximation to the Faddeev equations (FCA), which has been proved to be reliable in [8, 9] and has been applied to the study of the $NK\overline{K}$ system [10] and the results compare favorably with those of the Faddeev approach in [4] and those of the variational approach in [3]. There are some well known two body states in this sector, such as $\Lambda_c(2595)$ in DN with its coupled channels interaction [11, 12], $D_{s0}^*(2317)$ in KD interaction [13–15], and the hypothetical $X(3700)$ generated in isospin I=0 $D\overline{D}$ interaction [13]. These states are the clusters in the FCA in our study.

2 Formalism

Following [9, 10, 16], we will apply the FCA to study the charm sector. The FCA approximation to Faddeev equations is depicted in Figure 1.

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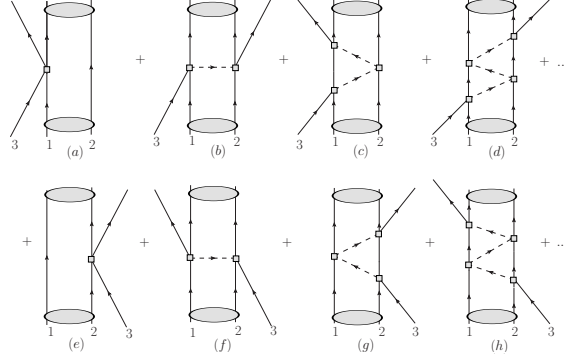
Figure 1: Diagrammatic representation of the FCA to Faddeev equations.

With this meaning of the FCA, the equations can be written by two partition functions T_1, T_2 which sum all diagrams of the series of Fig. 1,

$$T_1 = t_1 + t_1 G_0 T_2, \tag{1}$$

$$T_2 = t_2 + t_2 G_0 T_1, \tag{2}$$

$$T = T_1 + T_2, \tag{3}$$

where T is the total three-body scattering amplitude. The amplitudes t_1 and t_2 represent the unitary scattering amplitudes respectively. And G_0 is the propagator of particle 3.

3   Results

In this part we show the results of our investigation in that systems $\overline{K}DN$, NDK and $ND\overline{D}$. In Figure 2 (left) we show the results of $|T|^2$ for the $\overline{K}\Lambda_c(2595)$ scattering in the $\overline{K}DN$ system. We find a peak around 3150 MeV, slightly above the threshold of the $\Lambda_c(2595) + \overline{K}$ mass (3088 MeV) and below the threshold of the $\overline{K}DN$ system (3298 MeV), of which the width is about 50 MeV. For the system $\overline{K}DN$, its quantum numbers are $C = +1, S = -1$ and $J^P = \frac{1}{2}^+$ since we only consider the interaction among the components in $L = 0$.

In the NDK system, we obtain $|T|^2$ for the $ND_{s0}^*(2317)$ scattering shown in Fig. 2 (right). We found a peak around 3050 MeV which is about 200 MeV below the $N + D_{s0}^*(2317)$ threshold and the width less than 10 MeV. We also do not find a counterpart in the PDG and the quantum numbers, with positive strangeness, correspond to an exotic state.

Finally we obtain the T matrix, for the $ND\overline{D}$ interaction by means Eq. (3), and show the results of $|T|^2$ in Figure 3. From this figure we can see that there is a clear peak of $|T|^2$ around 4400 MeV and the width is very small, less than 10 MeV. The peak appears below the $ND\overline{D}$ and $NX(3700)$ thresholds and corresponds to a bound state of $NX(3700)$. This
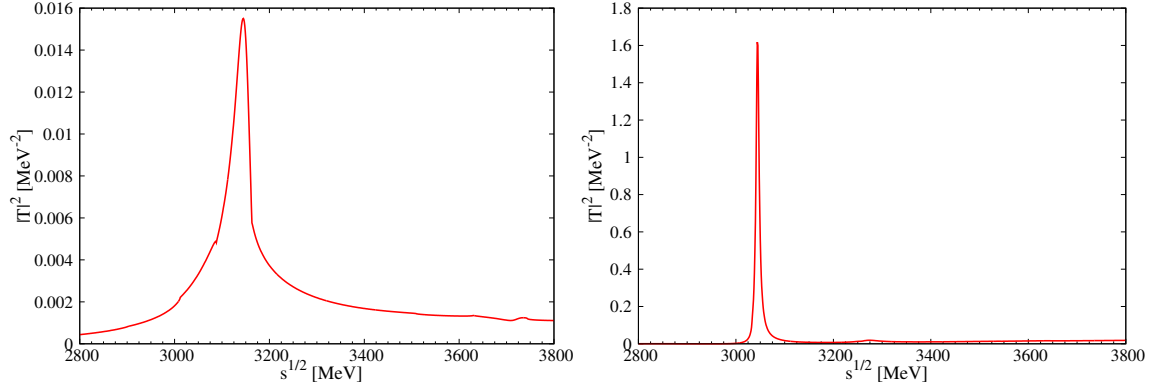
Figure 2: Modulus squared of the scattering amplitude for $\overline{K}\Lambda_c(2595)$ (left) and $ND^*_{s0}(2317)$ (right).

would be a hidden charm baryon state of $J^P = \frac{1}{2}^+$ which appears in the same region of energies as other hidden charm states of $J^P = \frac{1}{2}^-$ obtained in [17, 18].
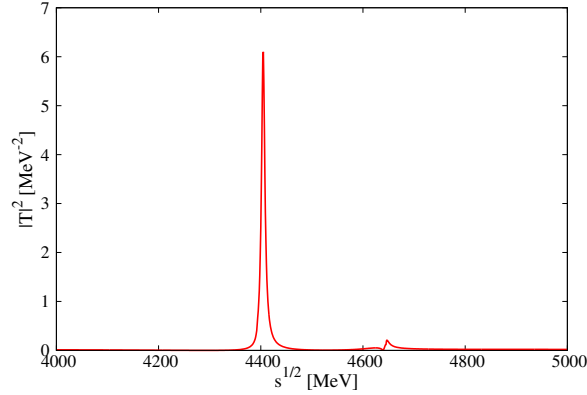
Figure 3: Modulus squared of the the $NX(3700)$ scattering amplitude.

4   Conclusion

In all cases we find bound or quasibound states, relatively narrow, with energies 3150 MeV, 3050 MeV and 4400 MeV, respectively. All these states have $J^P = 1/2^+$ and isospin $I = 1/2$ and differ by their charm or strangeness content, $S = -1, C = 1$, $S = 1, C = 1$, $S = 0, C = 0$, respectively. We hope that the work stimulates other theory calculations and future experiments in Facilities of FAIR or BELLE upgrade to prove our findings.

Acknowledgements

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